SUST Journal of Engineering and Computer Sciences (JECS), Vol. 16, No. 1, 2015

# Optimum Electrostatic Desalting Efficiency of Alfulla Crude Oil

Babiker K. Abdalla[1], Gurashi A.Gasmseed[2], Mohamed M. Elnour[1], Abbas M. Ahmed[1],

College of Postgraduate and Scientific Research, Karary University[1]
Chemical Engineering Department, University of Science of Technology[2]
Karama.eng@karary.edu.sd

*Received: 24/05/2014*
*Accepted: 02/07/2014*

***ABSTRAC*** - The main variables that impact the crude oil desalting process were analyzed by developing mathematical models that represent the variation of Alfulla crude oil density, conductivity and viscosity as function of different parameters. An increase or decrease of these parameters has two opposite effects. First, a decrease in oil density and viscosity implies a significant increase in the settling rate of water to be processed. This decreases equipment depreciation; on the other hand, crude oil conductivity increases exponentially with some parameters such as temperature, which implies a higher rate of power consumption. This study was developed to determine the optimum parameters at which a maximum desalting efficiency and a maximum economic benefit occurs. It was concluded that the optimum parameters are, Crude Oil flowrate is 80 % of the feed, Pressure is 1.1 MPa, temperature is 135 $^{0}$C, amount of washing water is 3% of the feed, interface level at 580 mm, differential pressure is 60 MPa, amount of demulsifier is 70 ppm and distributed water is available capacity of the tanks.

**Keywords:** *Alfulla crude oil, desalting, density, viscosity, conductivity.*

***المستخلص.*** *تم تحليل المتغيرات الأساسيه التي تؤثر في عملية إزاله الأملاح من الخام البترولي بتطوير نمازج رياضايه للكثافه والموصليه واللزوجه لخام الفوله كدالة فيها مختلف المتغيرات. للزايدة والنقصان في هذه المتغيرات أثرين متضادين. الأول إنخفاض في لزوجة وكثافة الخام يؤدي الي زياده ملحوظه في معدل ترسيب الماء والذي تتم معالجته. والذي بدوره يؤدي الي خفض تأكل الأجهزه. ومن ناحية أخري تتصاعد موصلية الخام لوغرثميا مع البعض من هذه المتغيرات كدرجة الحرارة مثلا حيث يؤدي ذلك الي رفع كمية الطاقه المستهلك. تم تطوير هذه الدراسة لتحديد المتغيرات المثالية لنتحصل علي كفاءة عالية لوحده ازالة الأملاح ومن ثم الحصول علي اعلي فائده اقتصادية منها. ولقد خلصنا الي أن القيم المثلي للمتغيرات هي: معدل سريان 80% وضغط 1.1 ميغا باسكال و درجة حرارة 135 درجة مئوية و ماء 3% ومستوي تداخل 580 ملم و فرق ضغط 60 ميغا باسكال والدملسفير 70 جزء من المليون كما يوزع الماء علي حسب سعة الخزان.*

## *INTORDUCTION*

Heavy crude oil is becoming an increasingly more important in terms of crude oil refining. This is not especially true due to the fact that this type of feedstock is generally cheaper in the international market [1]. There are three different types of crude oil in Sudan; these are heavy, medium and light crude oils. Alfulla is classified as heavy of these three types and represents 62% of the national total production [2]. However our trend has decided refining all of this heavy crude oil. Processes which require special attention is the electrical desalting. This process is performed prior to atmospheric distillation and it is main purpose is to reduce significantly the oil's salt content [1]. This is of special importance because of the high salt content in oil can be harmful to most equipment. In the specific case of process parameters, we found that it is fixed according to an operations manual that was made by engineering companies that were not familiar with the properties of Alfulla crude oil [3]. Also, it is to be noted that while most properties of this type of oil have been studied, there on the parameters has not or, at least, it has not been widely reported. The main concern of our research was the determination of the dependence of certain crude oil properties on different parameters. The knowledge of this dependence, in addition to providing valuable information about Alfulla oil, can be used to explore the effect of many parameters in the desalting process [3]. Crude oils are complex mixtures obtained from many parts of the world, and all crudes contain varying degrees of impurities [1]. These impurities consist of naturally occurring water, salts, solids and metals as well as added contamination from well stimulants, gathering methods, storage and transportation. Adverse effects of these impurities are excessive corrosion, fouling and unit upsets. These effects can result in shortened unit run lengths and reduced equipment reliability [8]. To minimize these effects, the refiner often washes the crude oil with water, and uses a desalting vessel to remove the added water and most of the inorganic contaminants from the crude prior to distillation in the crude unit [6]. Common desalter types and a brief description of them are given below:

- Electrical desalting, an electric field is induced by AC or DC current in the oil and water mixture to enhance water coalescence.
- Chemical desalting - surfactant chemicals are used to aid water coalescence
- Chemical and electrical desalting, a hybrid of electrical and chemical methods
- Gravitational separation, typically a large tank or drum which allows water and water borne contaminants to separate due to density difference between the water and oil phases [6].

The type, size and series stages of desalting facilities chosen are dictated by the individual refiner based on refinery specific requirements and limitations. The fundamental functions of desalters are the following:

- Remove chloride salts, typically calcium, magnesium, and sodium to minimize corrosion in the crude unit overhead system. This corrosion is caused by hydrochloric acid which is formed by hydrolysis of the magnesium and calcium salts during the distillation process.
- Remove solids and sediment that cause erosion or abrasion of equipment. Deposition of solids in the preheat exchanger train can lead to plugging of tubes or fouling which results in reduced heat transfer and higher energy consumption.
- Minimize unit upsets by preventing water slugs from tankage to be charged directly to the distillation column [5].

A detailed description of how desalters operate is beyond the scope of this paper. However, a summary of the major variables and their expected effect on the desalter operation follows:

- Crude oil properties, because desalters rely on the density difference between oil and water, lower gravity (higher density), higher viscosity crudes make it more difficult to separate water from the crude, and hence more difficult to desalt.
- Desalting temperature and pressure, generally desirable desalting temperatures are in the range of 250°F to 300°F (120°C to 260°C). The upper temperature limit is to avoid vaporization of the crude oil in the desalter, or to prevent damage to the electrical grid insulator bushings [4].
- Residence time, adequate residence time is essential for oil-water separation. Heavier crudes require longer residence time because the gravity difference between the oil and water is reduced. For low gravity crudes, the required water residence time can be two hours. Chemical emulsion breaker selection

may have a significant effect on oil under carry in the water which is caused by in adequate residence time.

**The need to desalt crude oil**

The salts that are more frequently found in the crude oil feed stocks are sodium, calcium, and magnesium chlorides ($NaCl_2$, $Ca\ Cl_2$ and $Mg\ Cl_2$). If these compounds are not removed from oil several problems arise in the refining process. The high temperatures that occur downstream in the process could cause water hydrolysis, which in turn allows the formation of hydrochloric acid (HCl) [7]. The presence of such substance implies serious corrosion problems in the equipment [8].

## *MATERIALS AND METHODS*

**The desalting process**

Desalting can be performed in single stage or in two stages, depending on the requirements of the process. Dehydration efficiency of a desalter is usually 95% in one stage and up to 99% in two stages [6]. If mixing is good, dehydration efficiency can be compared to desalting efficiency as most of the salt passed from the organic phase into the water phase. In actual operation, water and oil are preheated and mixed in a 1:20 ratio. It is common that the demulsifier substance is also added usually 0.005 to 0.01 lb/barrel [7].

**Analysis of the parameters affected on the Desalting process:** Generally settling rate depends highly on temperature. Liquid density and viscosity usually decrease with temperature. The effect is even greater regarding viscosity as the dependence is exponential. This means that increasing operation temperature will raise settling rate settling rate and therefore, improve separation. In a given desalter, separation improvement means that a larger quantity of oil can be desalted in the same time. This would suggest that a higher temperature is more convenient. However, crude oil conductivity increases with temperature and so does the power requirement of the process. Additionally, higher temperatures imply an increase of heating costs.

Given these opposing facts, it is expected that there is an optimum temperature. In the case of Maya feedstock it was necessary to know the dependence of density, viscosity and conductivity on temperature in order to determine if an optimum temperature exists.

**Results of Property Testing:**

**Temperature:** The desalting temperature is determined according to desalting criterion as shown:

$$v \alpha \Delta\rho\mu \qquad (1)$$

v: settling velocity, $\Delta\boldsymbol{\rho}$: is difference between a density of water and crude, $\mu$: is viscosity of crude oil.

Notice that when crude viscosity increase, settling velocity decrease so it is better to keep viscosity at low value by increasing a temperature but when a temperature increase this means $\Delta\rho$ will be very small, which is proportional with velocity so increase of temperature means $\Delta\rho$ small means settling velocity low but we cannot compare the benefit of decreasing viscosity by small negative effects of $\Delta\rho$, which we have another method to improve it so designer goes to neglect it. We will go to decrease the viscosity –by increasing temperature – up to reach near to maximum degree of temperature.

**Maximum available degree of a temperature**

when temperature increase , the conductivity of crude oil increase so this cause a short circuit for transformer so firstly we should build up the crude's conductivity -temperature curve and when conductivity reach critical value the value that urged transformer to trip- this is Amax degree of temperature so the designer choose safety temperature below this value.

Here no need to build up this curve because the rated current is available 200 Am so *the max degree of temperature* is that a temperature keep the current reach 200 Am and according to this we can decide *the max available degree of temperature**,** which is $135^0C$, according to Alfulla crude type.*

Notice that it is a different from design operating temperature but surely it is closed to operating temperature that designer set according to crude's conductivity temperature curve (130 $^0$C) [2], settling criterion $\Delta\rho\mu$, interface level and washing water ratio that will discuss later.

**Settling time:** It is very important factor in desalting system

$$R_t \ \alpha \ vQ \qquad (2)$$

$R_t$: retention time, v: volume of desalter, Q: volumetric flow of oil.

The retention time has positive proportional with the volume of desalter and inversely with the flowrate so retention time is increased by reduces the flow of oil because we can't change the volume of desalter, so 80% flowrate is suitable in our system during check of desalter efficiency.

**Pressure:** First, we should consider that designer choose operating pressure 1.1 MPa. The pressure should set at value that is prevent crude components to evaporate because generated gases will reduce a size of desalter and then degrade a performance and if gases in the top reach electrode plates, damage will be occur so it is very important to increase the pressure and put in our mind the design pressure of desalter and electrode plates. According to crude analysis result we can decide an optimum pressure in design steps, but this is operation so let us choose 1.2 or 1.1 .it is suitable primary value of pressure.

**Washing water-Oil ratio:** as we know the function of washing water is a washing salts of crude after ionizing salts in water so when amount of water is increased this will enhanced salt removing but also lead to increase a conductivity .so suitable amount of water should be decided . We will start by 6 % by volume according to type of our crude then increase it gradually up to reach 120 Am of primary current, it is so far from rated current 200.

**Interface level: A** weak AC field is formed between interface (oil-water) and bottom electrode plate. So a weak electric field work will determine the separation performance on the desalter because it reduces the load on DC by coalescence of a big drop of water. So if this field is stopped or reduced this will affect the current; and will increase rapidly due to the increase of load above the plate field which is a DC field.

If the interface level is high -being near the bottom electrode- the conductivity will increase up to a critical value (200 Am). A short circuit occurs and in the other hand if the interface level is low this will affect the AC. This will lose some oil blow down with water. So to determine the interface level vender advice for max value can followed the vender advice for max value because this will depend on the height of bottom electrode. Also give some space to keep it less than vender value. It can be found that conductivity is enough for the separation (here is the primary current). So this will try to set it at 580 mm then increase and increase it up to the primary current till it will reach 120 Am (it is a safe value, since the rated current is 200 Am). During this the distance between bottom electrode and the interface level should be know.

**Pressure drop in mixing valve:** A dramatic increase of differential pressure might form stable emulsion that would be hard to break up. So it will be chosen according to viscosity, amount of washing water and demulsifier dosage but experimentally for our crude type around 0.6 bar (60 MPa)

**Demulsifier ratio and type:** it is so important to break up the emulsion so injects amount of demulsifier is very important and it is vary from crude to crude according to viscosity but experimentally sometimes reach near 100 ppm for heavy crude so let us put initial value at 80 ppm . To distribute this amount of demulsifier on crude, dilution by water method is used but the amount of water should decided to keep the distribution perfectly so for amount of demulsifier 80 ppm it is better to use distributed water more and more and two demulsifier tank can be used at the same time and demulsifier should be test not for efficiency alone but for the time of affects and should be less than retention time of desalter. We will choose 80 ppm and the ratio of distributed water is available capacity of tanks.

**Trial and Error method:**

In this method we are going to put a consistent temperature at $135^0$C, and under pressure 1.2 MPa and we will play on the other parameters up to get optimum result so we can now remove this two parameters –pressure and temperature- and write down The others parameters as below to play with it:

- ✓ Initial amount of washing water is 6%
- ✓ Initial interface level at 580 mm
- ✓ Initial differential pressure is 60 MPa
- ✓ Initial amount of demulsifier is 80 ppm and distributed water is available capacity of tanks.

If the optimum amounts is determined and affects of increase and decrease of above parameters are studied, we should try to change the temperature by increase it again for example 2 degree (137 C) and continue study above parameters again and determine it as optimum value then increase temperature again 2 degree and so on up to max available temperature or test of performance give us good result.

This is trial and error method, notice that designer give us space to determine operation parameters according to change of our feed but we should play in ranges that he decided.

**Optimum amount of washing water determine method:**

First set a parameter at:

- ✓ Crude flowrate is 80 % of normal feed
- ✓ Pressure value set at 1.1 MPa
- ✓ temperature value set at 135 $^o$C.

***RESULTS AND DISCUSSIONS***

**Temperature effects on Alfulla crude oil density,** it was determined in accordance to ASTM-D-1298 [9]. The results are shown in Figure (1). The correlation that best fits this data behavior is the following:

$$d_0 = - 0.79\ T + 1205 \qquad (3)$$

**Temperature effects on Alfulla crude oil viscosity,** the standard ASTM-D-445 [10] was used for this purpose. The test was performed at several crude oil temperatures. The appropriate correlation was:

$$v = 6.87*10^{11}\ e^{(-0.075T)} \qquad (4)$$

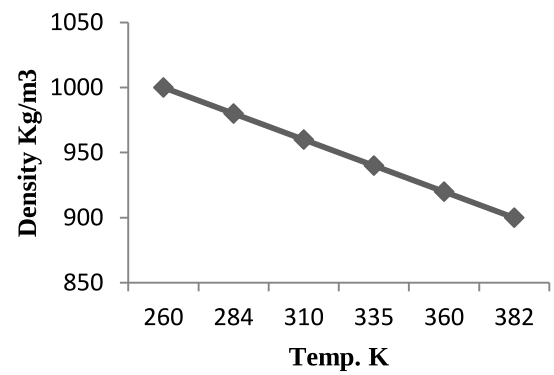


**Figure 1: Density of Alfulla crude oil as function of temperature**

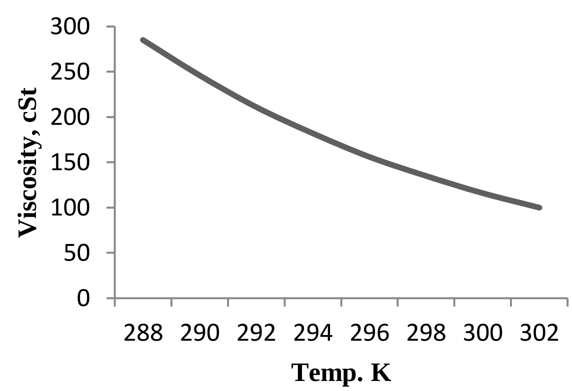


**Figure 2: Viscosity of Alfulla crude oil as function of temperature**

**Temperature effects on Alfulla crude oil conductivity,** this property was determined according to the procedures in ASTM-D-

3230 [11]. The correlation that best fits the experimental data is the following:

$$k = 0.02\, e^{(0.027T)} \qquad (5)$$

For comparison purposes, he results of Alfulla crude oil conductivity as a function of temperature are shown in Figure 3.

Results from these tests show that the properties of Alfulla oil are highly dependent on temperature. Also, Figure 3 shows that the conductivity of this crude is significantly different from other types of oil conductivity.

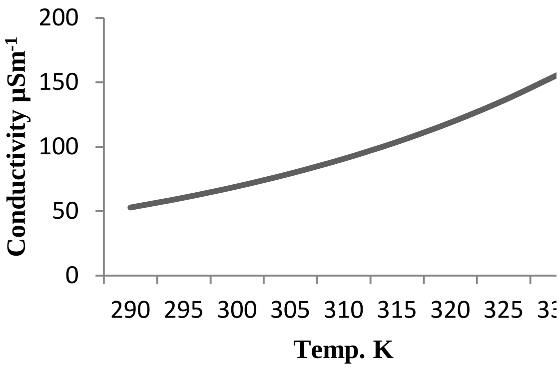


**Figure 3: Conductivity of Alfulla crude oil as function of temperature**

The difference in most values and the water is too low compare with amount that is depend on experimental data, may be because CPF dehydration is incomplete so oil with more water content sometimes more 3% is fed to Viscosity Breaking Unit (VBU). This problem of high cut of water due to less retention time or demulsifier addition in VBU feed tanks or bad drain system or else but when VBU use the first stage of desalter as a vessel (injection of water and demulsifier change to second stage) the problem partially solved, as we mentioned before we can say that the pressure value is decided directly 1.1 0r 1.2, which is play here as safety value more than performance value. The temperature can decide by analysis method but here we will depend on designer range for initial degree so let it at 135 $^{0}$C.

## *CONCLUSIONS*

If it is considered that current operation temperature is 378 K or 105°C it is evident that a change would be advisable. Such a change can be achieved in several different ways. However, in order to minimize additional heating costs, it is our recommendation that oil be preheated up to more than 135°C so that temperature decreases to 135°C when mixing with water occurs. This is convenient as oil is heated to around 280°C after desalting. If this was done prior to desalting, a profit could be easily obtained without extra investment in equipment. This kind of analysis is suitable for all crude types.

However, aiming it at Alfulla crude oil allowed a considerable improvement in the knowledge that currently exists on this kind of oil. This will allow future enhancements to be performed to Alfulla crude oil processing. Increase of temperature reduce the viscosity, and increase conductivity, where decreases in it increase viscosity. High pressure decreases the gas in the top, and increases the load on the Electrical Insulators and low pressure decrease gases generation.

Where high crude viscosity need more retention time, and Reduce the gas in ahead of desalter, low crude viscosity enhanced settling Process, and increase the gas in ahead of desalter, salts became as crystal and so difficult to remove when solubility is greater, and poor solubility enhanced settling Process. Increasing in the conductivity leads to short circuit, and elevation in settling rate. High Demulsifier ratio increase breaking rate then efficiency, also means more emulsion and corrosion. Washing water remove more salts and increase conductivity.

## *REFERENCES*

[1] Petroleum Monthly Statistics, (2004) Mexico, (PEMEX report), pp. 5.
[2] CNPC, Engineers Manual, (2006), (PE Sudan Branch, Viscosity Breaking Unit).
[3] CNPC, Engineers Manual, (2012), (PE Sudan Branch, Central Process Facilities).

[4] Auflem, I. H. (2002) Influence of Asphaltene Aggregation and Pressure on Crude Oil Emulsion Stability. Ph. D. Thesis: Norwegian University of Science and Technology, Trondheim.
[5] Heimbaugh, J. Jr. (1998) Dehydratation: the key to desalting crudes. Hydrocarbon Engineering.
[6] Gary and Handwerk. (1994) Petroleum refining technology and economics. Marcel Dekker, 3th Edition. New York.
[7] Harris, R. (1996) Use desalting for FCC feedstocks. Hydrocarbon Processing, PP. 63-65.
[8] Warren, K. (2002,). New tools for heavy oil dehydration. Society of Petroleum Engineers. Richardson, Texas, PP. 45-62.
[9] ASTM D 1298 method. (1986) “Standard test method for density, relative density (specific gravity), or API gravity of crude petroleum and liquid petroleum products by hydrometer method”.
[10] ASTM D 445 method. (1988) “Standard test method for kinematic viscosity of transparent and opaque liquids (and calculation of dynamic viscosity)”.
[11] ASTM D 3230 method. (1997) “Standard test method for salts in crude oil (electrometric method)”.

**Table 1: Comparing between actual operation condition of Viscosity Breaking Unit (VBU) plant and experimental operation condition**

| Items | VBU Currently Status | Experimental data |
|---|---|---|
| Pressure(MPa) | Around 0.9 MPa | 1.1-1.2 |
| Temperature(C) | Less than 130 | 135or more |
| Washing water % by volume | 3% | Around 8% |
| Interface level | Around 600 mm | due to conductivity (rated current) |
| Differential pressure | Around 45 kPa | Not more than 70 kPa |
| Demulsifier amount | 63 ppm | Close to 100ppm |
| Washing water injection status | Just first stage | All stages |
| Demulsifier injection status | Just first stage | All stages |
| Efficiency of desalters | 25% | More than 75% |